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Spray Penetration into Peanut Canopies with Hydraulic Nozzle Tips

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The spray penetration into peanut canopies with single- and twin-row planting systems at three growth stages was investigated with four different types of hydraulic nozzle tips (flat fan, hollow cone, twin jet and air induction). The nozzles were operated at 276 kPa pressure, 6·4 km h^{-1} travel speed, and 0·5 m above the top of canopies. The canopy leaf area index (LAI) and height were measured for each test and correlated with spray deposits at the bottom and middle of peanut canopies. Spray deposits at the top, middle and bottom of canopies were determined with a spray mixture containing water and a fluorescent tracer. The concentration of spray samples were corrected with the calibration of the photo degradation of the tracer exposed to direct sunlight, under artificial shade and in a dark room. Plants with single- and twin-row planting systems received significantly different spray deposits within peanut canopies. For all four nozzles during the growth season, the spray deposits decreased dramatically from the top to the bottom of canopies, and also tended to linearly decrease as LAI increased. Compared to the flat fan nozzle at the bottom of canopies at 75 days after planting, the air induction nozzle produced 2·6 times higher spray deposits for single-row plants and 1·6 times higher spray deposits for twin-row plants. During the three growth stages, the air induction nozzle produced the highest mean spray deposit at the bottom of canopies, followed by the twin jet and then hollow cone nozzles. The conventional flat fan nozzle had the lowest spray penetration performance among the four types of nozzles.

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1. Introduction

Pesticide application is a major component of peanut production costs in the southeastern United States. The annual pesticide consumption for all farm uses has steadily increased every year, partially because pesticide prices are relatively low compared to using other pest control tools and crop prices. Pest management guidelines provide little information that is helpful to peanut growers in selecting appropriate pesticide delivery methods because recommendations are for constant rates applied over the whole growing season. Insecticides and fungicides have traditionally been applied to peanuts 5–10 times per year as foliar sprays to control insects and diseases within and at the bottom of peanut canopies.

An individual peanut plant has a green oval leaf shaped canopy (*Fig. 1*). It develops flowers around the lower portion of the plant and produces pods and seed underground. During the period between 40 and 100 days after planting, the vegetative growth of a peanut plant can increase four to five fold with dramatic increases in main stem nodes, number of branches, leaf area, and plant height (Tewolde *et al*., 2002). Peanut plants may lose some foliage during later growing stage when peanut pegs reach maturity. The pesticide spray application method should be properly selected to deliver chemicals adequately and efficiently into peanut canopies during the high vegetative growth stage.

Many field tests have been conducted to determine the effectiveness of chemicals with assessment methods and combinations of pesticides to control soilborne (Csinos, 1987; Damicone & Jackson, 1996; Rideout *et al*., 2002) and foliar (Johnson *et al*., 1985; Brenneman *et al*., 1990) peanut diseases. However, Sumner *et al*. (2000) reported that methods to apply chemicals into the peanut canopies for leaf spot disease control could significantly influence the application efficiency of fungicides.

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Fig. 1. Peanut plant structure

Conventional hydraulic flat fan pattern nozzles are recommended for spraying herbicides to control weeds. This type of nozzle is also commonly used to discharge insecticides and fungicides to peanut canopies to avoid having to change nozzles frequently. In addition, growers use the same size nozzles throughout the growing season. However, the spray penetration in peanut canopies during the high vegetative growth stages is very poor with the flat fan nozzles (Zhu *et al.*, 2002). The average spray deposits at the top of canopies are 10·5 times higher than at the middle and 62 times higher than at the bottom of the canopies while diseases and pest insects are most commonly found inside and at the bottom of canopies. The efficiency of spray application is greatly influenced by plant structure and shape (Hall, 1991) and spray techniques (Juste *et al.*, 1990). Applying pesticides inside peanut canopies from stems and leaves close to the soil surface to the top leaves with a customised spraying technique could result in great cost reduction, less environmental pollution, and less chance of drift damage to other crops.

During the last several decades spray nozzles have been improved considerably to increase application accuracy. Many research reports have been released using new spray nozzle tips to improve pesticide delivery methods and to increase pesticide spray application efficiency (Miller *et al.*, 1990; Womac *et al.*, 1992; Hoffmann & Salyani, 1996; Womac & Bui, 2001; Giles *et al.*, 2002). Air induction hydraulic nozzles developed recently to reduce spray drift also provide satisfactory spray coverage and uniform spray patterns (Derksen *et al.*, 1999). For hydraulic nozzles, air assistance could greatly increase the spray deposit efficiency and reduce the spray deposit variability even under wind conditions (Nordbo & Taylor, 1991).

Different types of hydraulic nozzle tips have their own characteristics and, thus, may have potential for increasing spray application efficiency for different types of crop canopy. Twin jet nozzles produce two separate flat fan spray sheets, whereby the front spray sheet might slightly disturb the canopy and open up space for droplets from the trailing spray sheet to better penetrate some canopies. Hollow cone nozzles produce droplets with tangential trajectories that might penetrate some canopies by opening horizontal gaps between leaves. Air induction nozzles discharge a higher proportion of spray in larger droplets that might more readily reach the lower of canopy than could that from conventional flat fan nozzles. However, very little research has been done to investigate the potential of using these nozzle tips compared to the conventional flat fan nozzles to improve pesticide spray accuracy for different size peanut canopies during the growing season. The objective of this research is to evaluate spray penetration performances in peanut canopies at different growth stages with four types of hydraulic nozzles.

2. Materials and methods

Three spray penetration tests were conducted at 46, 75, and 104 days after planting, representing three different growth stages during crop year 2002. The cultivar Georgia Green was planted with both single- and twin-row planting systems at a population of 22 seeds m^{-2} in Faceville type soil on 10 May 2002. Peanut plants were irrigated with a surface drip irrigation system managed with 70% of the amount of water suggested by the Irrigator Pro program (Davidson *et al.*, 2000). The total precipitation and irrigation that the peanut plants received during the growing season was 458 mm. Plant spacing between two rows on a single twin-row bed was 0·23 m, and the distance from the middle line of the two rows to the middle line of the adjacent two rows was 0·91 m. The spacing between two plant rows with the single-row system was 0·91 m. To protect plants from foliar diseases, ground spray applications of fungicides were made every 2 weeks for a total of seven applications during the growing season.

The spray penetration into peanut canopies was evaluated with four different types of hydraulic nozzles:

80°conventional flat fan pattern nozzle (TeeJet 8003VS, Spraying Systems Co., Wheaton, IL, USA), hollow cone nozzle (TeeJet D4-DC25-HSS, Spraying Systems Co., Wheaton, IL, USA), low pressure air induction nozzle (TurboDrop® XLV-025, AgroTop GmbH, Obertraubling, Germany), and twin jet flat fan nozzle (TwinJet TJ60-8003VS, Spraying Systems Co., Wheaton, IL, USA). The field conditions for the three tests are listed in Table 1. Twenty randomly selected plants from a single-row bed and another twenty plants from a twin-row bed were used for all three tests. Five different plants were treated on each single-row bed and twin-row bed by each nozzle type. The sprayer was travelling at 6·4 km h^{-1} from west to east during the tests. The operating pressure for all nozzles tested was 276 kPa. Each nozzle was calibrated before the tests. The flow rates of nozzles at 276 kPa were 1·10, 1·01, 0·96, and 1·10 l min^{-1} for the flat fan nozzle, the hollow cone nozzle, the air induction nozzle, and the twin jet nozzle, respectively. All tests were conducted between 10:00 and 11:30 in the morning. Wind velocity was measured at 0·5 m above the top of the canopy for every test.

For single-row plants, three nozzles of each type were used to uniformly distribute spray across the entire canopy and the middle nozzle was positioned directly over the plant row [*Fig. 2*(*a*)]. For twin-row plants, two nozzles of each type were used to discharge droplets to cover all plants in the twin rows, and the centreline between the two nozzles was positioned over the middle line of the twin rows [*Fig. 2*(*b*)]. All nozzles were mounted 0·5 m above the top of plants and spaced 0·45 m apart. Sprays were vertically discharged toward canopies with an average rate of 225 l ha^{-1}.

Spray samples at the top, middle and bottom positions in each canopy (*Fig. 2*) were collected with 35 mm diameter and 10 mm depth petri dishes. The positions of the petri dishes for the bottom sample under canopy were placed on the soil surface; however, the height of the middle and top petri dishes was adjusted according to the plant height for each test. The height of samples at the top of canopies was the same as the plant height, and the height of samples at the middle of canopies was the half of the plant height. The petri dishes at the top and middle positions were supported with vertical ring holders that could be adjusted vertically and radially on 1 cm diameter metal bars. The metal bars were permanently installed 15 cm away from the centre of each individual plant for the entire season. The three petri dishes were radically separated to avoid interference of collecting droplets. The petri dishes were collected 30 min after spraying and stored in 125 ml wide-mouth glass bottles. All spray samples were

Table 1
Field conditions of three tests to evaluate spray penetration into peanut canopies

Test	*Days after planting*	*Wind speed m s^{-1}*	*Wind direction, deg*	*Ambient temp., °C*	*Relative humidity, %*	*Solar radiation, W m^{-2}*	*Single-row plants*			*Twin-row plants*		
							H, m*	*W, m*	*LAI*	*H, m*	*W, m*	*LAI*
1	46	1·5	73	30	67	547	0·20	0·48	2·20	0·19	0·71	2·76
2	75	0·5	74	32	69	598	0·40	0·92	6·58	0·40	1·09	7·47
3	104	1·3	75	32	72	745	0·45	0·96	6·25	0·42	1·14	5·93

* *H*, average plant height; *W*, average plant width; LAI, average plant leaf area index.

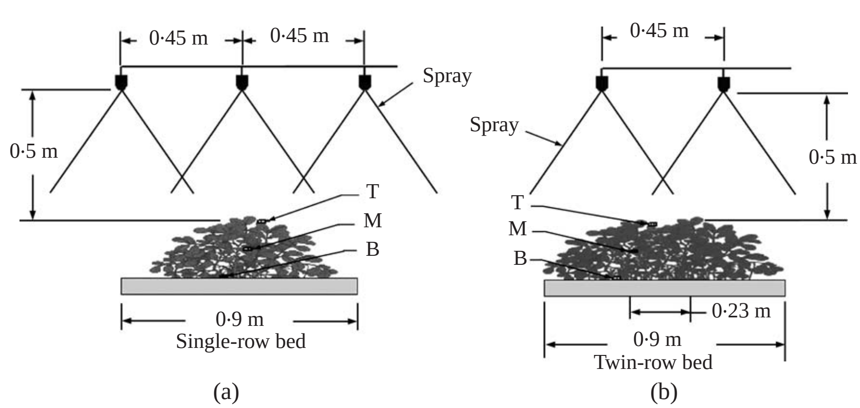

Fig. 2. Nozzle arrangement for spray penetration tests at three growth stages: (a) for single-row plants, and (b) for twin-row plants; T, M, and B represent spray sample positions at the top, middle, and bottom of canopies, respectively

immediately put into insulated boxes after collection and then stored in a refrigerator until analysed.

The spray mixture contained water and a fluorescent tracer, fluorescein containing 30% sodium salt, at a concentration of $0{\cdot}264\,\mu g\,\mu l^{-1}$ for all tests. The concentration of each spray sample was determined with a liquid chromatography (LC) analyser consisting of a Shimadzu Model RF-551 fluorescence detector. The spray deposits from the petri dishes were dissolved in purified water and adjusted to pH 9·2 by adding sodium carbonate. Details on the analysis of the spray deposits from the petri dishes are given in Zhu *et al*. (2002).

The photo degradation of fluorescein exposed to direct sunlight and under artificial shade was determined. A volume of spray mixture ($10\,\mu l$) with a concentration of $0{\cdot}264\,\mu g\,\mu l^{-1}$ was deposited into three groups of 12 petri dishes. Petri dishes in the first group were stored in a dark room. The second group was placed outside and exposed to direct sunlight at an ambient temperature of about 33°C and solar radiation of $724\,W\,m^{-2}$. The third group was placed outside near the second group but under artificial shade. Then one sample was taken from each group at 10 min intervals and dissolved in 40 m*l* water with pH value of 9·2 for concentration analysis. The degradation of fluorescein under different conditions over time was used to adjust the sample fluorescence reading (reported as the peak height) at the bottom, middle, and top of canopies as explained later.

The leaf area index (LAI) for each peanut canopy in every test was measured using an LI-COR® LAI-2000 plant canopy analyser. The LAI values were taken under artificial shade (Zhu *et al*., 2002). The height and width of each canopy were also measured prior to each test.

Data were analysed by one-way ANOVA, and differences among means were determined with Duncan's New Multiple-Range Test using ProStat version 3·01 for windows (Poly Software International, Inc., Pearl River, NY). All significant differences were determined at the 0·05 level of significance.

3. Results and discussion

3.1. *Photo degradation*

Figure 3 shows the photo degradation of fluorescein exposed to direct sunlight, under artificial shade, and in the dark room from 0 to 110 min. Peak heights from LC analyser were very consistent for all samples in the dark room during 110 min, and the average peak height was 7470. Peak heights for samples under direct sunlight and shade decreased dramatically in the first 30 min and then tended to become stable. The average peak height for

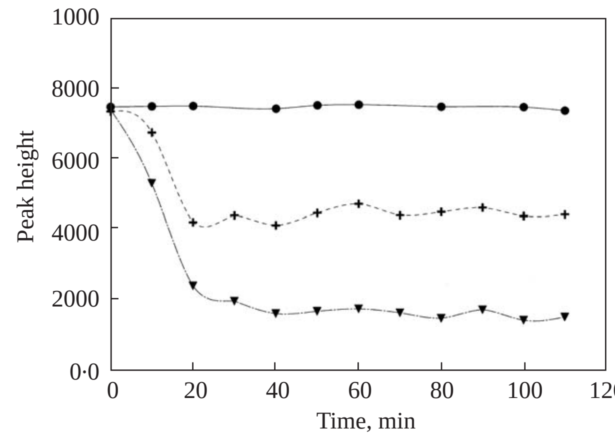

Fig. 3. Calibration of photo degradation of fluorescein exposed to direct sunlight (▼), under artificial shade (+), and in the dark room (●)

samples under direct sunlight and shade between 30 and 110 min was 1635 and 4440, respectively. Spray deposits at the top of canopies were corrected by multiplying the peak height by the ratio of 7470–1635, and deposits at the middle and bottom of canopies were corrected by multiplying the peak height by the ratio of 7470–4440. The final spray deposit was reported as the volume of spray efflux per square centimetre based on spray volume collected in a petri dish.

3.2. *Deposits at three growth stages*

Table 2 shows the average spray deposits discharged from four types of nozzles at the top, middle and bottom of peanut canopies at 46 days after planting with single- and twin-row planting systems, respectively. The height, width and LAI at this growth stage were 0·20 m, 0·48 m and 2·20, respectively, for single-row plants; and were 0·19 m, 0·71 m and 2·76, respectively, for twin-row plants. The spray deposits at the top of canopies from the four nozzles ranged from 1·822 to $2{\cdot}064\,\mu l\,cm^{-2}$ for single-row plants, and from 2·128 to $2{\cdot}888\,\mu l\,cm^{-2}$ for twin-row plants. Among the four nozzles for both single- and twin-row canopies at 46 days after planting, the twin jet nozzle delivered the highest spray deposits at the middle and bottom of canopies, and the flat fan pattern nozzle discharged the lowest deposits at the bottom of canopies. The spray deposit at the bottom of canopies from air induction nozzle was $0{\cdot}210\,\mu l\,cm^{-2}$ for single-row plants and $0{\cdot}236\,\mu l\,cm^{-2}$ for twin-row plants. The air induction nozzle discharged the second highest deposits at the bottom of canopies at 46 days after planting among the four nozzles. Data in Table 2 also illustrated that spray deposits within peanut canopies between two planting systems were considerably

Table 2
Average spray deposit in μl cm^{-2} at the top, middle and bottom of peanut canopies at 46 days after planting with single- and twin-row planting systems

Nozzle Type	*Average spray deposit μl/cm^{-2}*					
	Single-row planting system			*Twin-row planting system*		
	Top	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
Flat fan	1·982^{ab} (18)	0·874^{b} (40)	0·120^{a} (51)	2·321^{ab} (21)	1·089^{a} (51)	0·209^{a} (24)
Hollow cone	1·822^{a} (18)	0·591^{a} (38)	0·148^{ab} (43)	2·888^{b} (27)	0·832^{a} (46)	0·218^{ab} (21)
Air induction	1·826^{a} (24)	0·602^{a} (36)	0·210^{bc} (23)	2·604^{b} (23)	0·830^{a} (39)	0·236^{bc} (30)
Twin jet	2·064^{b} (15)	1·025^{c} (38)	0·264^{c} (36)	2·128^{a} (8)	1·166^{a} (27)	0·259^{c} (35)

Note: Coefficients of variation (%) are given in parentheses; means in a column followed by different letters are significantly different (probability < 0·05).

Table 3
Average spray deposit in μl cm^{-2} at the top, middle and bottom of peanut canopies at 75 days after planting with single- and twin-row planting systems

Nozzle Type	*Average spray deposit μl/cm^{-2}*					
	Single-row planting system			*Twin-row planting system*		
	Top	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
Flat fan	1·871^{b} (15)	0·605^{b} (42)	0·058^{a} (50)	1·913^{a} (33)	0·774^{c} (57)	0·052^{a} (43)
Hollow cone	1·561^{a} (12)	0·426^{a} (20)	0·102^{b} (45)	2·315^{b} (40)	0·450^{a} (13)	0·061^{a} (54)
Air induction	1·675^{a} (14)	0·648^{b} (36)	0·149^{b} (35)	2·108^{b} (19)	0·649^{bc} (35)	0·085^{b} (40)
Twin jet	1·781^{b} (9)	0·491^{a} (48)	0·081^{ab} (54)	2·053^{b} (8)	0·532^{ab} (47)	0·053^{a} (25)

Note: Coefficients of variation (%) are given in parentheses; means in a column followed by different letters are significantly different (probability < 0·05).

different since the spray settings for two planting systems were different.

When plants were 75 days old, the height, width and LAI were 0·40 m, 0·92 m and 6·58, respectively, for single-row plants; 0·40 m, 1·09 m and 7·47, respectively, for twin-row plants. At this growth stage, peanut plants were thick, and vines and leaves were fully developed. Table 3 shows the average spray deposits from four types of nozzles to the top, middle and bottom of peanut canopies at 75 days after planting with single- and twin-row planting systems. For single-row plants, there was no significant difference in spray deposits at the middle of canopies either between flat fan and air induction nozzles, or between hollow cone and twin jet nozzles, while the spray deposits from the flat fan and air induction nozzles were significantly higher than from hollow cone and twin jet nozzles. Similarly, the flat fan and air induction nozzles produced higher spray deposits at the middle of canopies with twin-row planting systems. Compared to the flat fan nozzle at the bottom of canopies, the air induction nozzle produced 2·6 times higher spray deposits for single-row plants and 1·6 times higher spray deposits for twin-row plants. The hollow cone nozzle also discharged significantly higher spray deposit at the bottom of canopies than the flat fan nozzle for single-row plants, but for twin-row plants the spray deposits from both nozzles at the bottom of canopies were not significantly different (Table 3). There was no significant difference in spray deposits between flat fan and twin jet nozzles at the bottom of canopies with both single- and twin-row planting systems.

When plants were 104 days old, the height, width and LAI were 0·45 m, 0·96 m and 6·25, respectively, for single-row plants; 0·42 m, 1·14 m and 5·93, respectively, for twin-row plants. Table 4 shows the average spray deposits from four types of nozzles at the top, middle and bottom of peanut canopies at 104 days after planting with single- and twin-row planting systems. Except for the twin jet nozzle, there were no significant differences among spray deposits from the other three nozzles at the top of single-row canopies while there were no significant differences in spray deposits at the top of twin-row canopies with hollow cone, air induction and twin jet nozzles. At the middle of canopies, the twin jet nozzle discharged significantly higher deposits than the other three nozzles for single-row plants while for twin-row plants the air induction nozzle discharged the highest deposits, but not significantly different from that discharged from hollow cone

Table 4
Average spray deposit in μl cm^{-2} at the top, middle and bottom of peanut canopies at 104 days after planting with single- and twin-row planting systems

Nozzle Type	*Average spray deposit μl/cm^{-2}*					
	Single-row planting system			*Twin-row planting system*		
	Top	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
Flat fan	1·987^{a} (16)	0·254^{a} (58)	0·056^{a} (66)	2·537^{b} (12)	0·454^{a} (44)	0·089^{a} (62)
Hollow cone	2·187^{a} (9)	0·322^{a} (46)	0·094^{b} (50)	2·154^{a} (15)	0·514^{ab} (30)	0·152^{c} (36)
Air induction	1·847^{a} (11)	0·295^{a} (43)	0·133^{c} (56)	2·272^{a} (15)	0·580^{b} (40)	0·131^{b} (55)
Twin jet	2·310^{b} (9)	0·423^{b} (59)	0·082^{ab} (35)	2·046^{a} (13)	0·455^{a} (37)	0·141^{bc} (46)

Note: Coefficients of variation (%) are given in parentheses; means in a column followed by different letters are significantly different (probability < 0.05).

nozzles. At the bottom of canopies, the highest deposit was discharged from the air induction nozzle for single-row plants and for twin-row plants from the hollow cone nozzle, but not significantly different from that discharged from twin jet nozzles. The flat fan nozzle discharged the lowest amount of spray deposits at the bottom of canopies with twin-row planting systems and lower spray deposit than hollow cone and air induction nozzles for single-row plants.

Spray deposits at the bottom of the canopies decreased substantially as peanut plants grew from 46 to 75 days and older. For example, the amount of spray deposited at the bottom of canopies by the flat fan nozzle at 46 days after planting was 2·1 times the amount deposited at 104 days after planting for single-row plants and 2·4 times the amount for twin-row plants. Similarly, spray deposited at the bottom of canopies by the air induction nozzle decreased 1·6 times for single-row plants and 1·8 times for twin-row plants when plants grew from 46 to 104 days after planting. Calculated from data in Tables 2–4, the average spray deposit of the three growth stages at the bottom of canopies ranged from 0·078 to 0·164 μl cm^{-2} with single-row plants, and from 0·117 to 0·151 μl cm^{-2} with twin-row plants for the four types of nozzles. For single-row plants at 75 and 104 days after planting, there was no significant difference between spray deposits at the bottom of canopies from each individual nozzle; however, spray deposits from each individual nozzles at the bottom of twin-row canopies at 104 days after planting were significantly higher than the deposits at 75 days after planting due to the average LAI at 75 days after planting was significantly higher than that at 104 days after planting.

At the three growth stages except for single-row plants at 75 days after planting, the spray deposit at the middle of canopies from air induction and hollow cone nozzles did not differ significantly. Also, these two nozzles had less variation in deposits at the middle of canopies than the other two nozzles when the plant

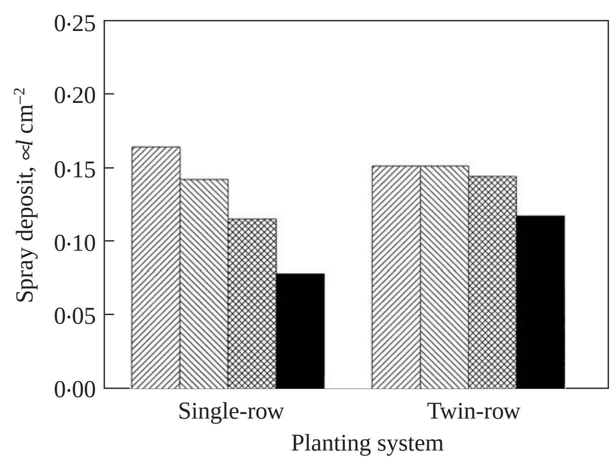

Fig. 4. Comparison of mean spray deposits averaged across three growth stages at the bottom of canopies with four different types of nozzles and two planting systems; ▨, air induction; ▧, twin jet; ▩, hollow cone; ■, flat fan

age increased from 46 to 104 days after planting (Tables 2–4). *Figure 4* shows the mean spray deposits at the bottom of canopies averaged across the three growth stages for each individual nozzle. The air induction, twin jet and hollow cone nozzles discharged higher mean spray deposit than the flat fan nozzle, and the air induction nozzle discharged the highest mean spray deposit among the four nozzles across the growing season. Data in *Fig. 4* also show that the air induction nozzle discharged 2·1 times as much spray at the bottom of canopies as the flat fan nozzle for single-row plants, and 1·3 times as much for twin-row plants. In many cases, spray applicators intend to use the same type of nozzles for pest controls during the whole growing season. Assuming the amount of spray deposited at the bottom of canopies by the flat fan nozzle is adequate to control diseases and insects with current pest management program recommendations, then to reach the same chemical dose rate at the bottom of canopies, the air induction nozzle would save 52% of the pesticide recommended for single-row plants and 23% for twin-row plants. Therefore, using the air induction nozzle instead of the flat fan nozzle might greatly reduce peanut production cost and the chemical contamination to the environment due to pesticide spray application. However, further study should be conducted to compare the biological impacts on peanut disease and insect control with the four types of nozzles to validate the test results.

3.3. *Sample height*

Spray deposits decreased dramatically from the top to the bottom of canopies for all four nozzles during the growing season. *Figures 5* and *6* show the spray deposits at different heights within canopies with single- and twin-row planting systems at 46, 75 and 104 days after planting from flat fan and air induction nozzles, respectively. The height of samples at the bottom of canopies shown in *Figs 5* and *6* was treated as zero. For the flat fan nozzle with the single-row planting system, the average spray deposit at the top of canopies at 46 days after planting was 2·3 times that at the middle position and 16·5 times that at the bottom position. With the same condition when plants were 75 days old, the average spray deposit at the top of canopies was 3·1 times that at the middle position and 32·3 times that at the bottom position. Similarly, for the air induction nozzle with the twin-row planting system, the average spray deposit at the top of canopies at 46 days after planting was 3·1 times that at the middle position and 11·0 times that at the bottom position, and was 3·2 times that at the middle position and 24·8 times that at the bottom position when plants were 75 days old.

3.4. *Leaf area index*

The peanut plant structure varied greatly with different growth stages. The average LAI of single-row plants increased from 2·20 to 6·58 between 46 and 75 days after planting and then decreased to 6·25 when plants were 104 days old. Similarly, the average LAI of twin-row plants increased from 2·76 to 7·47 between 46 and 75 days after planting and then decreased to 5·93 when plants were 104 days old. *Figure 7* shows the effect of the average LAI on spray deposits at the bottom of canopies with the twin-row planting system for the four nozzles. The spray deposits at the bottom of canopies tended to decrease linearly, as LAI increased, for all four nozzles. The linear regression equations for the spray deposit Y as a function of the leaf area index I_{LA} were:

$$Y = 0{\cdot}2973 - 0{\cdot}0344 I_{LA} \tag{1}$$

$$Y = 0{\cdot}3124 - 0{\cdot}0311 I_{LA} \tag{2}$$

$$Y = 0{\cdot}3595 - 0{\cdot}0368 I_{LA} \tag{3}$$

$$Y = 0{\cdot}3211 - 0{\cdot}0329 I_{LA} \tag{4}$$

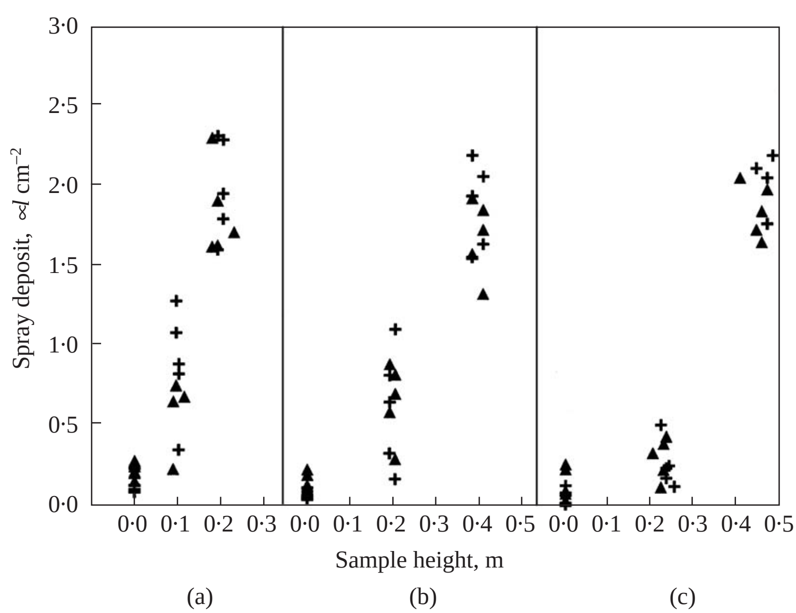

Fig. 5. Effect of sampling heights within peanut canopies on spray deposits from flat fan (+) and air induction (▲) nozzles for single-row plants at three different growth stages: (a) 46 days after planting; (b) 75 days after planting; and (c) 104 days after planting

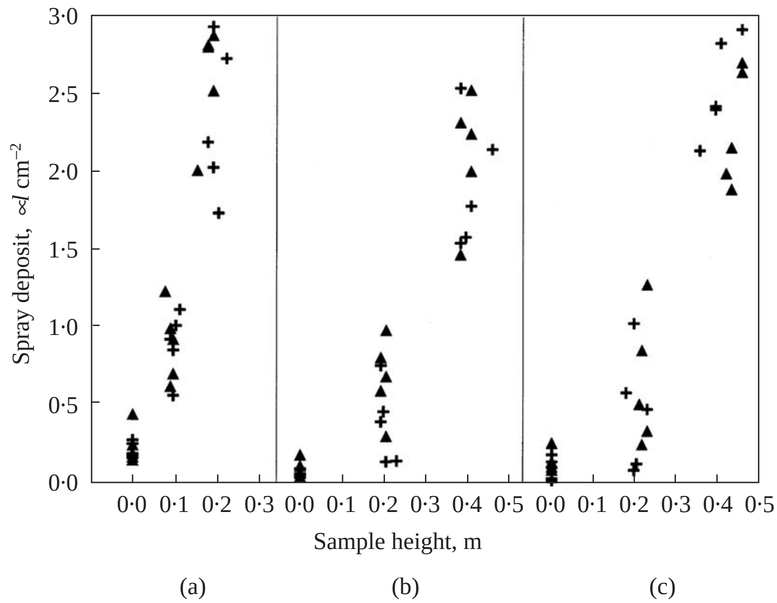

Fig. 6. Effect of sampling heights within peanut canopies on spray deposits from flat fan (+) and air induction (▲) nozzles for twin-row plants at three different growth stages: (a) 46 days after planting; (b) 75 days after planting; and (c) 104 days after planting

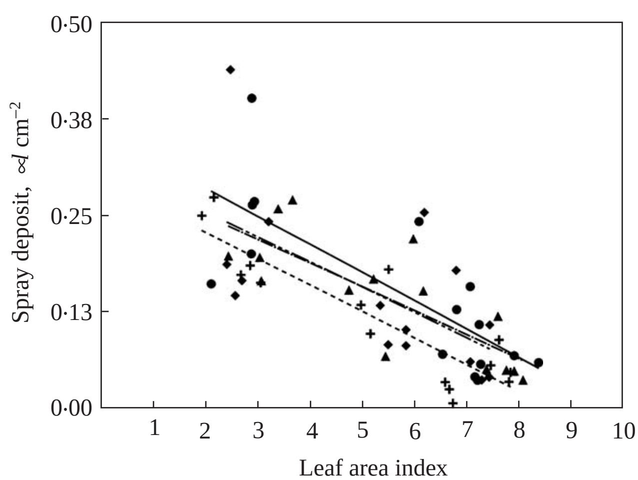

Fig. 7. Effect of leaf area index on spray deposits at the bottom of twin-row canopies discharged by four different types of nozzles; – –+–, flat fan; —·-▲-·, hollow cone; —●–, air induction; —··-◆·, twin jet

for flat fan, hollow cone, air induction, and twin jet, with values of the coefficient of determination r^2 of 0·89, 0·79, 0·77 and 0·62, respectively. Spray deposits at the bottom of canopies with the single-row planting system had similar linear relationship with LAI. At the bottom of twin-row canopies the spray deposit from the hollow cone nozzle was 0·152 μl cm^{-2} when LAI was 5·93 and was 0·06 μl cm^{-2} when the average LAI was 7·47. The flat fan nozzle always discharged significantly lower spray deposits at the bottom of canopies than any other three nozzles for all averaged LAI.

4. Conclusions

(1) The conventional flat fan nozzle deposited significantly less spray at the bottom of canopies during the three growth stages than the other three nozzles, and the air induction nozzle discharged the highest mean spray deposit at the bottom of canopies. The twin jet nozzle discharged higher spray deposits at the bottom of canopies than the hollow cone nozzle.

(2) Spray deposits decreased dramatically from the top to the bottom of canopies for all four nozzles during the growing season, and the spray deposits at the bottom of canopies also decreased substantially as peanut plants grew from 46 to 75 days and older. Air induction and hollow cone nozzles had less variation in deposits at the middle of canopies than twin jet and flat fan nozzles when plant age increased from 46 to 104 days after planting.

(3) Spray deposits at the bottom of canopies tended to linearly decrease as leaf area index increased for all four types of nozzles.

(4) For the leaf area index of 6·25 and 6·58 which occurred when single-row plants were 75 days and older, there was no significant difference between spray deposits at the bottom of canopies from each individual type of nozzles.

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